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Indian Standard

(Reaffirmed 2006)

METHOD FOR CREEP TESTING OF STEEL AT ELEVATED TEMPERATURES

PART 2 TENSILE CREEP STREES RUPTURE TESTING

(First Revision)

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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METHOD FOR CREEP TESTING OF STEEL AT ELEVATED TEMPERATURES

PART 2 TENSILE CREEP STRESS RUPTURE TESTING

(First Revision)

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Indian Standard

METHOD FOR CREEP TESTING OF STEEL AT ELEVATED TEMPERATURES

PART 2 TENSILE CREEP STREES RUPTURE TESTING

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 27 June 1983, after the draft finalized by the Methods of Physical Tests Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 A great variety of steels are used in service at elevated temperatures in chemical plants, high pressure boilers, steam turbines, internal combustion and jet engines, petroleum industries, etc. It is, therefore, essential to know the high temperature creep properties of such materials, for their efficient use and also for design purposes. The high temperature creep properties may be determined by the following two methods:

a) *Tensile creep testing* — This test method prescribes tests for the determination of the creep strain of metal test samples subjected throughout their duration to nominally constant tensile load and constant temperature conditions.

b) *Tensile creep stress rupture testing* — This test method prescribes tests for the determination of the time taken, for rupturing of the metal test sample, subjected throughout their duration to nominally constant tensile load and constant temperature condition.

0.3 This Indian Standard was first published in 1965. It has now been revised in light of the latest developments in the field of creep testing. While revising this standard, it was decided to cover the various methods of creep testing at high temperatures in different parts of the same standard. Accordingly, the methods have been covered in the following parts:

Part 1 Tensile creep testing — covering interrupted and non interrupted creep testing at elevated temperatures

Part 2 Tensile creep stress rupture testing—at elevated temperatures

0.4 With the publication of the two parts of this standard, IS : 3408-1965* and IS : 3409-1965† shall be withdrawn.

0.5 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960‡.

1. SCOPE

1.1 This standard (Part 2) prescribes method for the determination of the time required for rupturing of metal test sample subjected throughout their duration to nominally constant tensile load and constant temperature conditions, in single and multi-test sample rupture testing machines, for time up to 100 000 h. It defines the properties to be determined and the terms used in describing tests and test samples.

1.2 This standard is applicable to un-interrupted and interrupted tests on test samples of circular and rectangular cross-section and on test samples of circular cross-section having a notch and also on test samples from tubes.

1.3 The standard is applicable to the conditions of heating the test sample in an electric resistance or radiation furnace in air or atmosphere pressure, unless other media are specifically agreed upon in advance.

1.4 This standard is not applicable for conditions of rapid heating, rapid strain rates or too short times.

2. SYMBOLS

2.1 For the purpose of this standard, following symbols shall apply:

Symbol	*Description*
d	Diameter of test section of test samples of circular cross-section and inside diameter of the tube
D	Outside diameter of tube
D_n	Diameter of the parallel portion of a notched test sample of circular cross-section
d_n	Diameter of test sample at root of notch

*Method for non-interrupted creep testing of steel at elevated temperatures.
†Method for creep stress rupture testing of steel at elevated temperatures.
‡Rules for rounding off numerical values (*revised*).

Symbol	*Description*
a	Thickness of test section of test sample thickness of strip test sample cut from tube
b	Width of test section of test sample
r_n	Notch root radius or notch angle
K_t	Elastic stress concentration factor
r	Transition radius
L_o	Original gauge length
L_c	Parallel length of notched test sample
L_n	Parallel length of notched test samples including the width of the notch
L_t	Total length
L_u	Final gauge length
S_o	Original cross-sectional area of test section
S_u	Minimum cross-sectional area of test section after rupture
A	Percentage elongation after rupture
Z	Percentage reduction of area after rupture
h	hours (number of hours for the test)

3. TERMINOLOGY

3.0 For the purpose of this standard the following definitions shall apply.

3.1 Test Sample — There are two types of test samples on which the rupture best is carried out.

3.1.1 *Proportional Test Sample* — A test sample of circular cross-section with a gauge length, having a specified relation to the square root of the cross-sectional area, that is, an original gauge length equal to $5{\cdot}65\sqrt{S_o}$.

3.1.2 *Non-proportional Test Sample* — A test sample having a gauge length not specifically related to the cross-sectional area.

3.2 Gauge Length — The prescribed part of the test sample on which elongation measurements are made.

3.2.1 *Original Gauge Length* (L_o) — The gauge length before the test sample is strained.

3.2.2 *Final Gauge Length* (L_u) — The gauge length after the test sample has ruptured.

3.3 Stress

3.3.1 For an unnotched test sample the load on the test sample divided by the original cross-sectional area of the parallel portion gives the stress.

3.3.2 In a notched test samples the stress, referred to as the 'nominal stress' is the load divided by the initial cross-sectional area in the plane of minimum diameter, that is, at notch root.

3.4 Percentage Elongation After Rupture (A) — The permanent increase in length $L_u - L_o$ of the gauge length expressed as a percentage of the original gauge length L_o is given by:

$$\frac{(L_u - L_o)}{L_o} \times 100$$

NOTE—All measurements being made at room temperature.

3.5 Percentage Reduction of Area After Rupture (Z) — The maximum decrease of the cross-sectional area ($S_o - S_u$) expressed as a percentage of the original cross-sectional area S_o, that is, $\frac{(S_o - S_u)}{S_o} \times 100$.

3.6 Rupture — Complete fracture of the test sample within the original gauge length or at the root of the notch under constant load and under constant temperature.

3.7 Time to Rupture — The total time at the test temperature and the test load between the commencement of the test and the rupture of the test sample.

3.8 Elastic Stress Concentration Factor (K_t) — For notched test samples, the ratio of the maximum axial stress calculated for elastic conditions to the nominal stress at the same load.

3.9 Diameter of Test Sample at Root of Notch (d_n) — The diameter of a notched test sample of circular cross-section in the plane of minimum diameter, that is, normal to the axis of the test sample at the notch root (*see* Fig. 2 and 3).

3.10 Notch Root Radius (r_n.) — The radius of the profile of the notch root in a plane parallel to the axis of the test sample.

3.11 Notch Angle (l) — The angle between the flanks of a V-notch, the flanks being tangential to a circle of radius r_n.

3.12 Minimum Parallel Length (L_n) — The minimum parallel portion of the test sample required for satisfactory distribution of stress and temperature at the notch.

3.13 Notch Depth — The distance measured normally to the test sample axis from the outside of the parallel portion to the notch root, that is,

$$\frac{D_n - d_n}{2}.$$

3.14 Notch Construction Ratio — The ratio of the difference of cross-sectional areas of the parallel portion and at the notch root to the cross-sectional area of the parallel portion, that is,

$$\frac{D_n^2 - d_n^2}{D_n^2}.$$

3.15 Notch Strength Ratio — It is a ratio obtained by dividing the nominal stress required to rupture a notched test sample in a specified time, by the nominal stress required to rupture a plain test sample in the same time.

3.16 Notch Rupture Life Ratio — It is the ratio obtained by dividing the time required to rupture a plain test sample loaded at the same stress.

4. SELECTION AND PREPARATION OF TEST SAMPLES

4.1 The selection and preparation of test samples and the location of test samples shall be stated in the materials specification or shall be as agreed with the inspecting authority.

4.2 Care should be taken in the selection and preparation to ensure that the metallurgical structure and mechanical properties of the test sample are representative of the original test material.

5. TEST SAMPLE

5.1 General

5.1.1 The cross-section of the parallel portion of the test sample shall be circular or rectangular except for strips cut longitudinally from tubes. There shall be gradual increase in cross-sectional area from the parallel length to the enlarged ends. Bars and wires may be tested in full section without machining (*see* Fig. 1 to 5).

5.1.2 The test samples shall be selected in accordance with the Tables 1, 2, and 3. It is recommended that the largest practicable size of test sample be used.

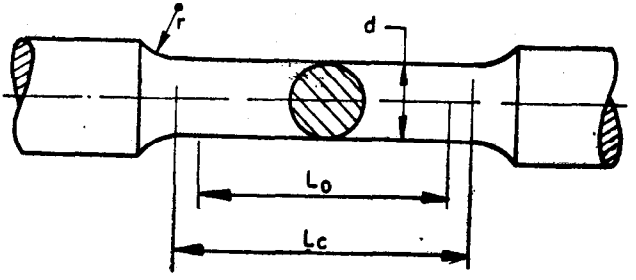

FIG. 1 TEST SAMPLE OF CIRCULAR CROSS-SECTION

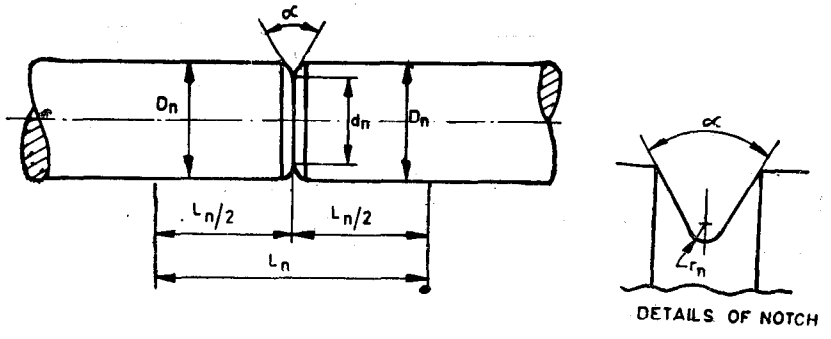

FIG. 2 NOTCHED TEST SAMPLE OF CIRCULAR CROSS-SECTION

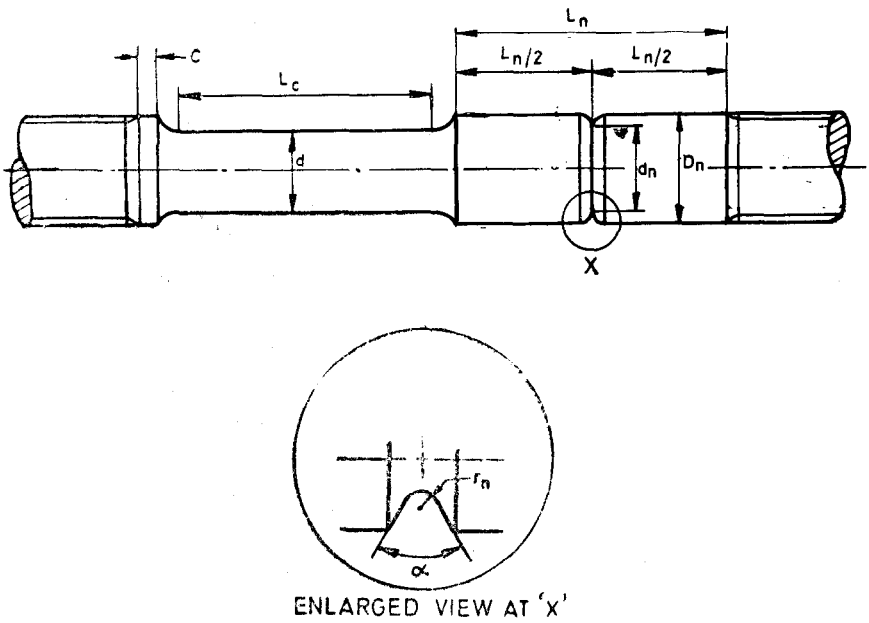

FIG. 3 COMBINED NOTCHED AND UNNOTCHED TEST SAMPLE

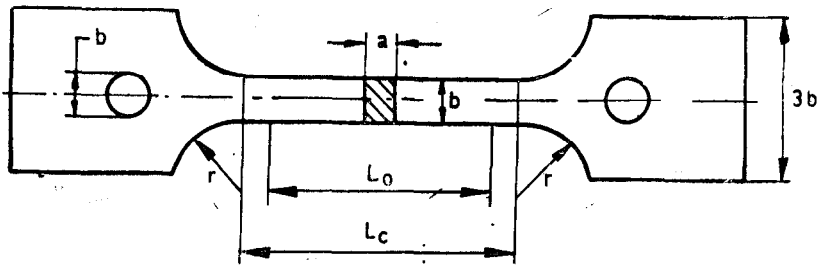

FIG. 4 TEST SAMPLE OF RECTANGULAR CROSS-SECTION

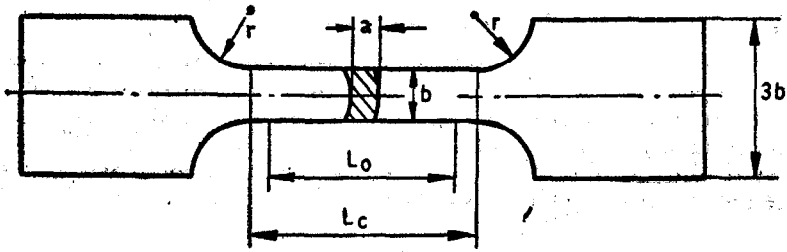

FIG. 5 STRIP TEST SAMPLE CUT FROM TUBE

5.2 Test Sample of Circular Cross-Section

5.2.1 The cross-section of the test sample shall be circular and there shall be a transition radius between the gripped ends and the parallel length (*see* Fig. 1 and 3). Except when the section size of the material precludes it, the original cross-sectional area shall be not less than 12·5 mm².

5.2.2 Test sample sizes other than those given in Table 1 are permitted provided they comply with the relationship $L_o = 5{\cdot}65\sqrt{S_o}$ that is $Lo \approx Sd$. If this relationship cannot be achieved, the gauge length shall be stated in the standard for the material, but in no case shall L_o be less than 3 times the diameter '*d*' of the test sample.

5.2.3 For machined test samples which do not conform to the dimensions given in Table 1, it is recommended that the transition radii shall be approximately equal to the diameter of the test sample in case of wrought metals and cast steel and approximately equal to twice the diameter of the test sample in case of other cast metals.

TABLE 1 DIMENSIONS OF TEST SAMPLES OF CIRCULAR CROSS-SECTION

(*Clauses* 5.1.2, 5.4.3, 16.1.1 *and* 16.2.1)

Cross-Sectional Area	Diameter	Minimum Gauge Length (*see* Note 1)	Minimum Parallel Length	Minimum Transition Radius, *r*	
				Wrought Metals and Cast Steel	Other Cast Metals
S_o	d	L_o	$L_c (\approx 5{\cdot}5\ d)$		
(1)	(2)	(3)	(4)	(5)	(6)
mm	mm	mm	mm	mm	mm
100	11·28	56	62	10	20
50	7·98	40	44	8	16
25	5·64	28	31	5	10
12·5	3·99	20	22	4	8

NOTE 1 — The values of L_o are equal to $5{\cdot}65\sqrt{S_o}$.

NOTE 2 — The ends of the test piece may be threaded to suit available adaptors provided the minor diameter of the thread is greater than *d*.

5.3 Test Samples of Rectangular Cross-Section

5.3.1 The dimensions of rectangular cross-section test samples given in Table 2 apply only for materials up to and including thickness of 10 mm (for thickness greater than 10 mm test samples of circular cross-section should be used). Unless otherwise specified, the thickness of the test sample shall be the full thickness of the material. In all cases the width of the test sample, *b*, shall be not less than its thickness, *a* (*see* Fig. 4).

TABLE 2 DIMENSIONS OF TEST SAMPLES OF RECTANGULAR SECTION

(*Clauses* 5.2, 5.3.1, 5.3.3, 5.4.1, 15.1.2, 16.1.2 *and* 16.2.2)

WIDTH	MINIMUM GAUGE LENGTH	MINIMUM PARALLEL LENGTH	MINIMUM TRANSITION RADIUS
b	L_o	$L_o (\simeq L_o + b)$	r
(1)	(2)	(3)	(4)
mm	mm	mm	mm
12.5	50	63	25
6	24	30	12
3	12	15	6

5.3.2 Test samples having width other than those given in Table 2 may be used and in such cases it is recommended that the minimum gauge length be not less than 4 times the width of the test sample and that the transition radius be at least twice the width of the test sample.

5.3.3 Elongation shall be measured on the appropriate gauge length stated in Table 2, unless otherwise specified by the standard for the material.

5.4 Test Samples from Tubes

5.4.1 *Strips Cut Longitudinally* — The dimensions of the test samples machined from strip should conform to the requirements given in Table 2 (*see* Fig. 5). Only the ends may be flattened for gripping in the testing machine. (For determination of cross-sectional area *see* **14.1**).

5.4.2 *Lengths of Full Section* — Tubes may be plugged at each end, but the length and shape of the plugs should be such that they do not interfere with free extension of the gauge length.

5.4.3 *Thick Tubes* — For tubes having a thickness, a, greater than 7 mm, it is recommended that a round test sample having dimensions conforming to the requirements given in Table 1 shall be used.

6. PRINCIPLE OF TEST

6.1 The test consists of maintaining a test sample at uniform temperature subjecting it to constant tensile load at that temperature until fracture occurs and determining the time to rupture and where applicable, the rupture ductility of the test sample.

6.2 Tests may be interrupted in the interests of obtaining data at intervals during the course of the test. Interruptions to testing may also occur in the interest of maintaining specified test conditions and can arise in multi-test sample testing as the result of the rupture of another test sample in the same loading system. Any variations of load or temperature outside the limits are restricted to the nearest minimum.

7. TESTING MACHINE

7.1 The test machine shall comply with the following requirements. However, for the purpose of temperature measurement, the use of sensors other than thermocouples is permitted by agreement.

TABLE 3 DIMENSIONS OF NOTCHED/UNNOTCHED TEST SAMPLE

(*Clauses* 5.1.2 *and* 15.1.2)

Cross-Sectional Area	Diameter of Test Section	Minimum Parallel Length	Diameter of Parallel Portion	Diameter at Root or Notch	Plain End	Parallel Length Including Notch	Notch Root Radius	Angle of Notch	Minimum Transition Radius	
									Wrought Metals and Cast Steel	Other Cast Metals
S_0	d	$L_c = L_o$	D_n	D_n	C	L_n	r_n	L		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
mm^2	mm	mm	mm	mm	mm	mm	mm		mm	mm
100	11·28	56	16·9±0·03	11·28±0·03	4	40	0·32±0·01	60±1°	10	20
50	7·98	40	11·28±0·03	7·98±0·03	4	28	0·23±0·01	60±1°	8	16
25	5·64	28	7·98±0·03	5·64±0·03	4	20	0·16±0·01	60±1°	5	10
12·5	3·99	20	5·64±0·03	3·99±0·03	4	14	0·11±0·01	60±1°	4	8

NOTE 1 — The values of L_o are equal to $5{\cdot}65\sqrt{S_o}$.

NOTE 2 — Difference between d and d_n not to exceed 0·01 mm.

7.2 The testing machine shall be calibrated in accordance with IS : 1828-1975* or other relevant standards over the load range for which it is to be used and shall comply with the requirements of Grade A. The testing machine should be capable of applying the load to the test sample without shock.

8. THERMOCOUPLES

8.1 Manufacture

8.1.1 The materials of thermocouples shall be of proven suitability for use at the test temperature and throughout the duration of the test. To ensure that the temperature of the thermocouple junction is not substantially affected by the flow of heat along the wires, it is recommended that the dimension of wire be the smallest practicable size.

8.1.2 The thermocouple shall be made from batches of wire that have been periodically calibrated over the working range against the recognized fixed points for thermocouple calibration or by comparison with a similarly calibrated and carefully maintained standard platinum/platinum-rhodium reference couple.

8.1.3 Refuse of thermocouples is not recommended unless recalibration has shown the original temperature/emf relationship to be maintained.

8.1.4 Rare metal thermocouples may be used for short time tests, that is for less than 2 000 h without intermediate recalibration but shall be annealed. They shall be recalibrated, if they have been used a number of times. When tests exceed 2 000 h, annealing and also recalibration may be necessary at the end of each test. It is recommended that thermocouples be recalibrated *in situ* or at immersion depths similar to operating conditions.

8.1.5 Thermocouple junctions shall make good thermal contact with the surface of the test sample and shall be suitably screened from direct radiation from the furnace wall. The remaining portions of the wires within the furnace shall be screened and completely insulated by a suitable covering.

8.2 Location of Thermocouples

8.2.1 In single test sample testing machines, three numbers of thermocouples shall be used for test sample having a parallel length of 50 mm or greater and not less than two thermocouples for test samples having parallel length of less than 50 mm.

*Method for load verification of tensile testing machines (*first revision*).

8.2.2 *For Multi-Test Sample Machines* — A thermocouple may be attached at the mid-point of the parallel length of each test sample. Alternatively in multi-test sample testing machines, thermocouples may be located at appropriate positions within the furnace, provided that temperature surveys along the test length of test sample show that the temperature complies with the requirements of Table 4.

9. HEATING AND SOAKING OF TEST SAMPLE

9.1 The heating period shall be between one to four hours, in order to bring the temperature approximately to the required test temperature. Precaution shall be taken to avoid heating beyond the desired temperature. On initial heating of the test sample from room temperature to that test temperature, the combined heating and soaking time should not exceed 24 hours of which at least 1 hour shall be at the required test temperature.

9.2 For tests on certain materials, at temperatures for which even short soaking time may significantly after the structure or high temperature strength, it is recommended that the heating and soaking time be as short as practicable.

9.3 In interrupted tests, the cumulative time at which any test sample is under heating and soaking conditions that is unloading shall be kept to a minimum.

10. TEMPERATURE CONTROL AND MEASUREMENTS

10.1 Temperature Control

10.1.1 While attaining the test temperature and prior to applying the load, or throughout the duration of the test, the temperature at any point within the gauge length of the test sample shall not deviate or exceed the specified temperature by more than the value given in Table 4, unless otherwise specified in the standard for the material.

10.1.2 The mean temperature shall normally be controlled within limits, much closer than those stated in Table 4, since these limits are intended to allow for variations in temperature which may occur. It is recognized that the temperature fluctuations outside these limits may occur, which may not necessarily invalidate subsequent results.

10.1.3 Closer control of temperature may be required for testing certain metals at temperature at which the creep-strength is markedly dependent on temperature, and also where it is known that temperature variations affect the functioning of the extensometer. In such cases, any alterations to the limits in Table 4 shall be decided by agreement.

TABLE 4 TOLERANCE ON TEST TEMPERATURE

(*Clauses* 8.2.2, 10.1.1, 10.1.2 *and* 14.5.1)

Test Temperature °C	*Tolerance on Test Temperature, °C	
	Over 10 h and Up to 100 h	Over 100 h
Up to and including 600	±2	±3
Over 600 up to and including 800	±2·5	±4
Over 800 up to and including 1 000	±3	±6

*The tolerances include the allowable deviations from all sources.

10.1.4 For temperature greater than 1 000°C the permissible variations shall be by agreement.

10.2 Temperature Measurement

10.2.1 Temperature measuring equipment with a sensitivity of 0·5°C shall be used to indicate the temperature of the test sample.

10.2.2 In general not less than three thermocouples, evenly spaced along the gauge length shall be used.

10.2.3 A continuous record of the temperature shall be made, or sufficient measurements of the temperature taken to indicate that the temperature requirements have been complied with, throughout the test.

11. LOADING OF TEST SAMPLES

11.1 The full load shall be applied to the test sample without shock and precautions shall be taken to ensure that the load is applied to the test sample as axially as possible. The applied load shall be maintained throughout the duration of the test, within 1 percent of that specified.

11.2 Depending on the material and the test conditions, the effects of rate of loading may be significant. To get comparable results the rate of loading for each type of material shall be approximately the same for all tests. The ratio of loading or the total time for the application of the load shall be recorded.

12. ASCERTAINMENT OF PROPERTIES

12.1 Measurement of Time to Rupture — The actual time required to rupture shall be measured to an accuracy of ±1 percent.

12.2 Measurement of Rupture Ductility

12.2.1 *General* — The measurements may be made when the test sample is cooled down to room temperature. While measuring rupture ductility precaution shall be taken to ensure proper contact between the broken parts of the test sample. More care shall be taken while measuring small test samples and test samples having low ductility values. To facilitate the measurement, a jig shall be used which will enable the broken pieces to be mated axially at the point of fracture.

12.2.2 *Measurement of Percentage Elongation* — The value (A) shall be calculated as follows:

$$A = \frac{\text{Measured extension}}{\text{Parallel length}} \times 100$$

$$= \frac{L_u - L_o}{L_o} \times 100$$

L_o and L_u (*see* **2.1**) shall be measured to an accuracy of $\pm$ 1 percent.

NOTE — The correct value of the percentage elongation may not be obtained unless fracture of the test sample has occured at a section situated within the middle third of the parallel length.

12.2.3 *Measurement of Percentage Reduction in Area* — The value (Z) shall be calculated as follows:

$$Z = \frac{S_o - S_u}{S_o} \times 100$$

13. PRESENTATION OF TEST REPORT

13.1 The test report of each test shall include the following:

a) Type of testing machine;

b) Relevant details of materials under test and the identity of the test samples;

c) Original dimensions and gauge lengths of the test samples;

d) Test temperature;

e) Approximate time to reach the test temperature and the soaking time prior to loading;

f) Stress applied;

g) Rate of loading or the time taken to apply the load;

h) Time to rupture or the duration of the test if it is terminated before rupture occurs;

j) Number, duration and time from the commencement of the test of any interruptions and deviations in load/or temperature, during the test;

k) Percentage elongation after rupture and the method of measurement;

m) Percentage reduction of area after rupture; and

n) Position of the fracture, if outside the middle third of the parallel length and any unusual features in its appearances.

14. NOTES AND RECOMMENDATIONS

14.1 Measurement of the Cross-Sectional Area

14.1.1 *Test Samples of Circular Cross-Section* — For the purpose of calculating the cross-sectional area, the diameter shall be measured to an accuracy of 0·01 mm.

14.1.2 For the purpose of calculating the cross-sectional area, of test samples of rectangular section and strip test samples cut longitudinally from tubes, the width and thickness shall be measured to an accuracy of 0.01 mm, except for thickness less than 2·5 mm which shall be measured to an accuracy of 0·2 percent. The cross-sectional area of a curved strip test piece having parallel edges is then calculated as follows:

$$S_o = ab\left(1 + \frac{1}{6} \times \frac{b^2}{Dd}\right) \text{ or}$$

$S_o = ab$ according to the accuracy required.

14.2 Measurement of Original Gauge Length (Interrupted Tests)

14.2.1 For the purpose of measuring the elongation, it is recommended that reference marks defining the original gauge length shall be located on the parallel portion of the test sample.

14.2.2 If this is not practicable, it may be expedient either to use reference marks on the enlarged ends, in which case the marks should be as near as practicable to the transition radii, or to use measurements of overall length between machined faces of the test sample. The result of this method gives the elongation, which may be influenced by the contribution of the transition portion of the test sample (between parallel length and shoulder). The magnitude of this contribution is not accurately known.

14.2.3 Greater accuracy may be achieved by using longer gauge lengths, that is gauge length exceeding $5{\cdot}65\sqrt{S_o}$. For these tests no upper limit is placed on the actual gauge length, provided that, where an extensometer is not used, the requirement specified in **12.2.2** can be met.

14.2.4 By prior agreement between the contracting parties, one of the following dimensions may be used as the gauge length L_o:

a) The 'equivalent elastic gauge length', that is, the parallel length which would give the same elastic extension as that measured experimentally by an extensometer attached to the reference marks on the enlarged ends of the test sample.

b) The parallel length.

c) The overall length measured over the ends of the test sample.

d) The actual dimension between the reference marks on the machined ends of the test sample.

14.2.5 When gauge length L_o is agreed to as given in **14.2.4** (a), (b), (c) or (d), it is recommended that:

a) the transition radius from the parallel length shall be approximately $d/2$ for circular test samples and $b/2$ for rectangular test samples.

b) the area of the cross-section of the enlarged ends shall be at least 50 percent greater than that of the minimum cross-sectional area of the test sample.

14.3 Temperature Measuring Instruments — The temperature measuring instruments shall have a sensitivity of 0·5°C or better. The instruments shall be calibrated over the working range at intervals not exceeding 1 year and the errors shall be recorded on the calibration certificate. Any instrument for measuring cold junction temperature shall be accurate to within 0·2°C.

14.4 Extension Measuring Instruments for Interrupted Tests — Instruments for measuring extension shall be calibrated at intervals not exceeding 1 year and the errors recorded on the calibration certificate.

14.5 Apparatus for Heating and the Control of Temperature — The apparatus shall be capable of raising the temperature of the test sample and maintaining it at the test temperature within the limits specified in Table 4.

15. GENERAL REQUIREMENTS OF TEST SAMPLES

15.1 These requirements shall be applicable for Tables 1, 2 and 3.

15.1.1 The ends of test samples may be threaded to suit available adaptors, provided the minor diameter of the thread is greater than d or d_n as appropriate.

15.1.2 The common requirements in Tables 2 and 3 have been selected with a view to discriminate between materials commensurate with ease of test piece manufacture and giving an elastic stress concentration commonly encountered in practice. Test samples which comply with the requirements of Tables 2 and 3 have an elastic stress concentration factor (K_t) of approximately 3·9.

15.1.3 For many materials, normal machining procedures affect the properties of the material at the root of the notch. It is therefore extremely important that only very light forces are applied during the finishing process. Notch contours should be checked by optical projection methods.

16. TOLERANCES

16.1 Parallelism

16.1.1 The parallel length shall not vary in diameter by more than 0·03 mm, in case of circular cross-section test samples (*see* Table 1).

16.1.2 The parallel length shall not vary in width by more than 0·03 mm, in case of rectangular cross-section test samples (*see* Table 2).

16.2 Co-axiality

16.2.1 The gripped ends of the test piece shall be co-axial with the parallel portion within a concentricity tolerance of $\pm 0{\cdot}03$ mm, in case of circular cross-section and notched and unnotched test samples (*see* Tables 1 and 3)

16.2.2 The width at the gauge length shall be symmetrical about the axis joining the centres of the locating holes within a tolerance of $\pm 0{\cdot}03$ mm, in case of rectangular cross-section test samples (*see* Table 2).

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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